Effect of Mid Plane Layer on Flexural Properties of Plies Under Transverse Loading

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الخلاصة

تم دراسة الطبقة الوسطية على متانة الانحناء ومعامل يونك. تم تحضير متراكبات من الايبوكسي- الياف زجاجية نوع E.سلحت المتراكبات بطبقات متعددة من الياف زجاجية عشوائية وحصيرة.تم دراسة الاجهاد المستعرض على متانة الانحناء ومعامل يونك باستخدام فحص الانحناء الثلاثي. اظهرت النتائج ان الطبقة الوسطية نوع حصيرة – حصيرة والتي تملك توزيع متجانس اظهرت متانة الانحناء ومعامل يونك عاليين وهي اعلى من من حصيرة –عشوائي وعشوائي –عشوائي.

الكلمات المفتاحية

الطبقة الوسطى، متانة الإنحناء، الإجهاد المستعرض.

Abstract

The effect of mid layer on flexural strength and young modulus were studied using Instron testing machine. E-glass/epoxy composites were manufactured using hand lay-up technique. The laminated composites were prepared with dimension (4x10x80) mm, Epoxy composites were reinforced with multidirectional layer of woven glass fiber and random glass fiber of stacking sequence $[M]_{16}$, $[R]_{16}$, $[M/R//M_1/M_1//R/M]s$, [//M/R//]s, and $[R/M//R_1/R_1//M/R]s$. The effect of transverse loading on flexural strength and young modulus was investigated for specimens subjected to Three-point bending test.

The results show that the mid layer (M_1/M_1) which had (homogeneous distribution) has higher flexural strength value and young modulus than mid layer (M_1/R_1) and (R_1/R_1).

Keyword

mid plane, flexural Properties, transverse loading.

1. Introduction

Fiber reinforced and laminated composites have proved their usefulness and high potential through many applications in various fields. In particular in air craft and space craft structures, components made from composite materials frequently are designed to withstand extreme loading conditions during service. Because in addition they have to meet strong fail-safe requirements, investigations of the failure behavior of composite materials and structures are important subjects in materials and engineering science. Among the various failure mechanisms that may develope in composite materials, like fibre or matrix cracking and fiber debonding, interlaminar fracture or delamination is the major failure process in laminated composites [1,3].

Investigation of damage in glass fiber reinforced plastics are used to analyze the interplay specimen, damage mechanism (fiber matrix, interface cracking) and the effect of local properties on the microscopic damage mechanism [2].

Kuboki [4] proposed a test method, under 3-point bending, to measure the critical strain energy release rate (Gc) for delamination in fibre-reinforced polymers (FRP) under out-of-plane (transverse) loading the difference of the fibre orientation used in this study was 90˚, i.e. one 90˚ layer in the mid-thickness and the rest 0˚ layers. Under Three-point bending, matrix shear cracking was firstly initiated in the 90˚ layer, mimicking the mechanism for delamination initiation in the FRP, when subjected to transverse loading. The matrix shear cracking led to delamination in the adjacent inter-laminar regions, of which area can be measured after the test. Marina [5], showed that the increase in the number of lateral multiple delimitations and broken fiber strands significantly reduces the residual ultimate strength of the laminated composites. Kim [6], estimates the flexural properties of three kinds of experimental fiber-reinforced composite (FRC) posts and to evaluate their potential use as posts. Experimental FRC posts were fabricated with glass, aramid, and UHMWP fiber.

2. METHODOLOGY

2. 1. Materials

Epoxy resin, type Quick mast 105, were provided by DCP/Jordan and hardener type HY935, the hardener was mixed with the epoxy resin ratio of 1:3, under the room temperature.

Epoxy Resin are impregnated by hand lay–up technique into glass fibers which are in the form of woven roving and chopped strand mat fabrics, to prepare sheets of 16 plies for epoxy/glass fiber composites of different sequences. A 16-plies of glass/epoxy laminate was manufactured using the sequences, (M) for mat and (R) for random glass fiber, the intermediate layers denoted by (//) between them, (s) refer to sequence as shown below $[M]_{16}$, $[R]_{16}$, [//M/R//]s, $[M/R//M_1/M_1//R/M]$s and $[R/M//R_1/R_1//M/R]_S$.

the samples were cut according to ASTM D790-84a [7] to test the specimens under transverse loading, Fig. (1).

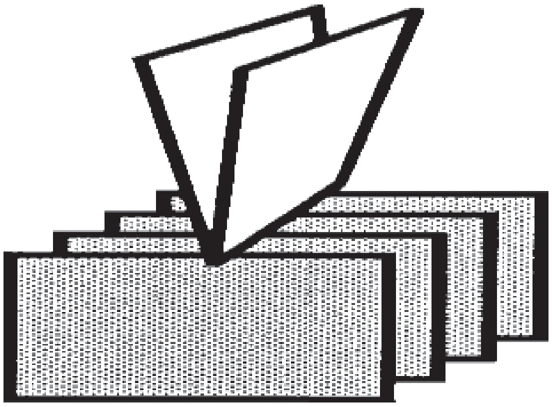

Fig. (1): Direction of load on specimens cutted in Transverse direction.

2. 2. Flexural test

the flexural test was performed on the Instron testing machine 1122 using the Three-point bending method according to ASTM D790-84a [7]. The specimen dimensions were 80 (mm) (L) x 10 (mm) (W) and had 4 (mm) thickness, Table (1). The specimens were tested at a crosshead speed of 0.5 (mm/min).

The strength of a material in bending is expressed as the stress on the outermost fibers of a bent test specimen, at the instant of failure. In a conventional test, flexural strength expressed in MPa is equal to:

$$\textbf{Flexural Strength} = 3PL / 2bd^2$$

Where, P = applied central load (N), L= test span of the sample (mm), b= width of the specimen (mm) and d = thickness of specimen under test (mm)

In each of the specifications the flexural modulus is defined in the same way, such that for a three-point bending test:

$$E_f = L^3 m/4bd^3$$

Where, E_f is the flexural modulus in GPa, L is the support span,*m* is the slope of the load/deflection curve, with *b* and *d* being the width and thickness of the beam, respectively.

Table (1): Recommended Dimensions for test specimens

Nominal specimen depth (mm)	Specimen width (mm)	Specimen length (mm)	Support Span (mm)
4	10	80	64

3. Results and Discussion

Higher flexural strength and flexural modulus were found for $[M]_{16}$,because woven roving glass fibers layer were continuous fibers and have long lengths, so that if these fibers are arranged a long span, all the loads will transverse and distributed evenly and the fibers will resistance to bend, so that the stacking layers of mat laminates give the high strength for these composites, as shown in Table (2).

Table (2): Flexural strength and flexural modulus of stacking sequence under transverse loading

Materials	Flexural strength (MPa)	Flexural modulus (GPa)
$[M]_{16}$	294	4.74
$[R]_{16}$	112	1.67

Due to the good interlocking between layers, the most failure mechanism associated with specimens was debonding with small splitting in all the layers.

In random composites, the flexural strength and flexural modulus were much lower than woven roving composites, because in random composites, the random orientation of fibers and ends of fibers induced stress concentration region forming micro cracking leading to fracture, for this reason random composites were broken easily and could not resist bending.

As shown in Table (2), the number of mat plies were eight layers as well as random plies, and the sequence of plies were (M/R).

For $[M/R//M_1/M_1//R/M]s$ specimen,the flexural strength and flexural modulus were higher than $[//M_1/R_1//]s$ because the mid layer was (M1/M1) which have high strength as compared to $[//M_1/R_1//]s$ specimen in which the mid layer was (M1/R1), because when the load was applied vertically to the specimen, all of the load will transverse across the mid layer (M1/M1) which had (homogeneous distribution) but in the mid layer (M1/R1) and (R1/R1), the random layer which had short fibers, the stress concentration will localize at the end of the fiber, so that decreasing in strength will occur, for this reason $[R/M//R_1/R_1//M/R]_S$, have lower strength and modulus, Table (3).

Table (3): Flexural strength and flexural modulus of stacking sequence under transverse loading based on alternative layers

Stacking sequence	Flexural strength (MPa)	Flexural modulus (GPa)
$[M/R//M_1/M_1//R/M]s$	210	4.213
$[//M_1/R_1//]s$	198	4.194
$[R/M//R_1/R_1//M/R]_S$	183	3.439

4. Conclusions

The flexural strength and flexural modulus depend on the number of plies, mid plane layer and sequences of plies, Woven roving composites have higher flexural strength and flexural modulus in transverse loading compared to random composites, for this reason, the specimens which consist of mat layer in the mid-plane layer and higher number of mat layers have higher flexural strength and flexural modulus, because in $[M]_{16}$, the distribution of fiber was along the specimen, while in random glass fiber, the ends of fiber may be considered as stress concentration points, this weak point causes the reduction in flexural strength, so that the flexural strength of mat is higher than random glass fiber.

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